THE REINFORCING EFFECTS OF HOUSELIGHT ILLUMINATION DURING CHAINED SCHEDULES OF FOOD PRESENTATION

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Pigeons' keypecking was maintained under two- and three-component chained schedules of food presentation. The component schedules were all fixed-interval schedules of either 1- or 2-min duration. Across conditions the presence of houselight illumination within each component schedule was manipulated. For each pigeon, first-component response rates increased significantly when the houselight was extinguished in the first component and illuminated in the second. The results suggest that the increase was not the result of disinhibition or modification of stimulus control by component stimuli, but appears to result from the reinforcement of responding by the onset of illumination in the second component. Additionally, the apparent reinforcing properties of houselight illumination resulted neither from association of the houselight with the terminal component of the chained schedule nor through generalization of the hopper illumination present during food presentation. The results of the present series of experiments are related to previous demonstrations of illumination-reinforced responding and to the interpretation of data from experiments employing houselight illumination as stimuli associated with timeout or brief stimuli in second-order schedules.

Key words: houselight illumination as primary reinforcer, chained FI schedules, pigeons

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Kelleher (1966a) identified a class of schedule arrangements termed *second-order schedules* according to which the behavior fulfilling the demands of a schedule contingency (the unit or component schedule) is treated as a unitary response that is itself reinforced in accordance with another schedule of primary reinforcement. For example, the behavior generated by a fixed-interval (FI) 2-min schedule might be treated as a unit of behavior and the completion of two consecutive units or component FI schedules might be required for the presentation of the primary reinforcer. Three general types of second-order schedules have been identified. Under a brief-stimulus schedule, the completion of each component schedule is accompanied by a momentary stimulus change (e.g., a change in keylight illumination) until the completion of the component schedule that fulfills the demands of the primary reinforcement schedule (e.g., Findley & Brady, 1965;

Stubbs, 1971). Similarly, under a token reinforcement schedule, the completion of the component schedule is accompanied by the delivery of a token stimulus that is later exchangeable for primary reinforcement following the completion of the demands of the primary reinforcement schedule (Kelleher, 1957; Malagodi, 1967a,b,c). According to a chained schedule, primary reinforcement is presented following the completion of a fixed sequence of component schedules, each of which is associated with a unique discriminative stimulus (Gollub, 1958; Kelleher & Gollub, 1962).

Component schedule stimuli within a chained schedule may serve a dual function, with each component stimulus occasioning responding in its presence (the discriminative function) and the presentation of each component stimulus reinforcing responding in the preceding component (the reinforcing function; see Gollub, 1977; Kelleher, 1966b). In order to separate the discriminative and reinforcing properties of component stimuli, studies have examined the effects of varying the order of component stimuli (e.g., Kelleher & Fry, 1962), presenting the component stimulus that accompanies food delivery in different portions of the chained schedule (Byrd, 1971), and interpolating stimuli associated with food presentation between components (Malagodi, DeWeese, & Johnston, 1973). Studies have also compared the rates of

responding during concurrent chained schedules to determine the reinforcing properties of component stimuli associated with different rates and probabilities of primary reinforcement (e.g., Autor, 1969).

In the present study, the chamber houselight was illuminated in various components of chained schedules of food presentation in order to examine the reinforcing properties of this common experimental stimulus. Changes in houselight illumination have been used frequently in experimental preparations as discriminative stimuli with the assumption that such changes have no reinforcing properties. For example, in comparing responding under paired and nonpaired brief-stimulus schedules, houselight illumination has been employed as the stimulus indicating the completion of a component schedule. In a paired brief-stimulus schedule the brief illumination of the houselight occurs with the completion of each component schedule and would thus be paired intermittently with a primary reinforcer. In a nonpaired brief-stimulus schedule the brief illumination of the houselight occurs with the completion of each component schedule, except the one ending with the presentation of a primary reinforcer. Comparing the performances generated under these two schedules may assess whether pairing the brief stimulus with a primary reinforcer establishes the brief stimulus as a conditioned reinforcer. However, if houselight illumination has preexperimental reinforcing properties, consideration of such properties would be required in the interpretation of data from such procedures.

EXPERIMENT 1
Method

Subjects

Three adult male White Carneau pigeons (P-1150, P-4214, and P-3519) were maintained at 80% of their free-feeding body weights. Each pigeon had previous exposure to simple schedules of food reinforcement prior to the present experiment, and each was individually housed with water and health grit continuously available.

Apparatus

A commercially available Lehigh Valley Pigeon Test Chamber (model 1519) equipped with a standard three-key stimulus panel was used. The dimensions of the experimental space were 34 cm from the floor to the ceiling and 36 cm from the stimulus panel to the rear wall. The stimulus panel was 34 cm wide. Only the right key was operative and could be transilluminated with different colored lights. The left and center keys were covered with metal plates. The key required a minimum force of 0.25 N to operate the circuitry. The chamber could be illuminated by a 1.6-W clear bulb (No. 1819) located 4.5 cm directly above the center key. The bulb was partially shielded by a metal cover that allowed light to be projected only towards the ceiling of the chamber. A food hopper containing mixed grain could be made available through a square (5.7 cm × 5.7 cm) aperture in the stimulus panel 9 cm below the center key. Illumination of the raised food hopper was provided by a 1.6-W clear bulb mounted above the feeder mechanism.

Standard electromechanical scheduling and recording equipment was located in an adjacent room. Ventilation was provided by an exhaust fan mounted to the chamber. White noise was present at all times.

Procedure

Each pigeon was exposed initially to an FI 2-min schedule of food presentation. Under these conditions the response key was transilluminated red, and the first response after 2 min produced 4-s access to mixed grain. During grain presentation both the keylight and houselight were extinguished, and the raised food hopper was illuminated.

Following several sessions, a chained FI 2-min FI 2-min schedule of food presentation was introduced. Under this schedule, the response key was transilluminated yellow during the initial FI 2-min schedule (the first component) and the first response after 2 min changed the response key from yellow to red and initiated a second FI 2-min schedule (the second component). The first response after 2 min in the second component produced food delivery. After grain delivery the first component was again in effect. Because of prolonged session durations and the tendency for first-component response rates to diminish within each session, the chained schedule was reduced subsequently to chained FI 1-min FI 1-min for Pigeons P-4214 and P-3519. The

Table 1

Summary of Experiment 1 conditions.

Pigeon	Schedule	Houselight Condition	Number of Sessions
P-1150	CH (FI 2-m)(FI 2-m)	ON/ON	38
	CH (FI 2-m)(FI 2-m)	OFF/ON	30
	CH (FI 2-m)(FI 2-m)	ON/OFF	48
	CH (FI 2-m)(FI 2-m)	OFF/ON	46
	CH (FI 2-m)(FI 2-m)	OFF/OFF	96
	CH (FI 2-m)(FI 2-m)	ON/ON	55
P-4214	CH (FI 2-m)(FI 2-m)	ON/ON	50
	CH (FI 2-m)(FI 2-m)	OFF/ON	158
	CH (FI 1-m)(FI 1-m)	OFF/ON	63
	CH (FI 1-m)(FI 1-m)	ON/ON	81
	CH (FI 1-m)(FI 1-m)	OFF/ON	50
	CH (FI 1-m)(FI 1-m)	ON/OFF	117
	CH (FI 1-m)(FI 1-m)	OFF/OFF	55
	CH (FI 1-m)(FI 1-m)	ON/ON	32
P-3519	CH (FI 2-m)(FI 2-m)	ON/ON	42
	CH (FI 2-m)(FI 2-m)	OFF/ON	38
	CH (FI 1-m)(FI 1-m)	OFF/ON	96
	CH (FI 1-m)(FI 1-m)	ON/OFF	52
	CH (FI 1-m)(FI 1-m)	OFF/ON	32
	CH (FI 1-m)(FI 1-m)	ON/OFF	78
	CH (FI 1-m)(FI 1-m)	OFF/ON	126
	CH (FI 1-m)(FI 1-m)	ON/ON	41

chained FI 2-min FI 2-min schedule was always in effect for Pigeon P-1150.

The conditions of Experiment 1 consisted of manipulations of the presence of houselight illumination during the two components. The manipulations included (a) houselight on throughout both components (ON/ON), (b) houselight on during only the first component (ON/OFF), (c) houselight on during only the second component (OFF/ON), and (d) houselight always off (OFF/OFF). The sequence of experimental conditions and the number of sessions in each are summarized in Table 1. Although the initial conditions for each subject were ON/ON followed by OFF/ON, the sequence of conditions varied thereafter as subjects P-4214 and P-3519 were exposed to chained schedules with shorter component schedule durations (as described above) and to avoid sequence effects.

The number of responses and duration of time spent within each component were recorded during each session. Each condition was in effect for at least 20 sessions and until no systematic changes were evident in the daily session measures for 20 sessions. Typically, sessions were conducted 6 days per week and were terminated following 15 grain deliveries under the chained FI 2-min FI 2-min schedule or 30 grain deliveries under the chained FI

1-min FI 1-min schedule. The number of grain deliveries provided under the two chained schedules was chosen in order to maintain sessions duration at a 1-hr minimum.

RESULTS

Rates and patterns of responding were strongly controlled by the placement of houselight illumination within the two components. Figure 1 shows representative cumulative records from each condition for Pigeon P-1150. The pen was reset following the completion of the second component. The diagonal line marked the completion of the first component. Each record displays an entire session. Only the cumulative records from Pigeon P-1150 are displayed. Cumulative records from the other subjects were generally consistent with those from Pigeon P-1150. The use of FI 2-min component schedules, rather than the FI 1-min schedules employed with the other pigeons, allows for clearer viewing of the record. Each record represents the final session of a condition, except that the first session of each OFF/ON condition is also displayed.

Record A shows responding maintained when the houselight was on during both components (ON/ON). Response rates during the first component were characteristically
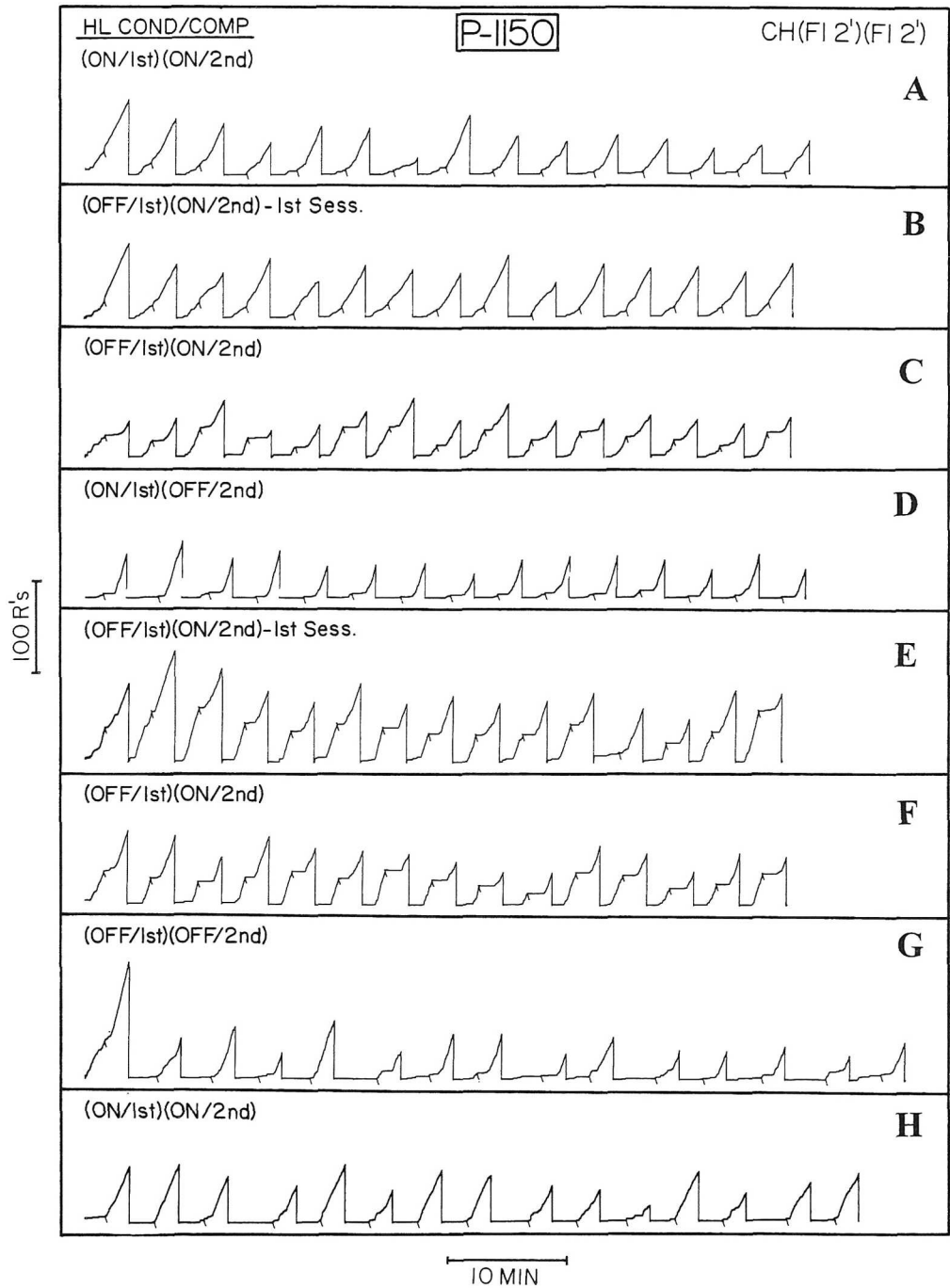
Fig. 1.   Sample cumulative records from each condition of Experiment 1 for Pigeon P-1150. Diagonal marks represent completion of the first component, and reset of the response pen represents completion of the second component.

low and irregular, with responding during the first component more likely to occur early in the session rather than later. Often a single response was emitted after the lapse of the 2-min interval. Second-component performance was characterized by a moderate rate of responding that either remained constant or positively accelerated until food presentation.

When the houselight was turned off during the first component and turned on when the second component began (OFF/ON), first-component response rates increased within the first session of the condition (record B). With continued exposure to the OFF/ON condition, first-component responding was further elevated and became distinctly positively accelerated; second-component response patterning changed similarly (record C—final session).

Reversing the placement of houselight illumination within the two components (ON/OFF) resulted in a decrease in first-component response rates and the continuation of positively accelerated patterning primarily in the second component (record D). Responding in the second component of the ON/OFF condition resembled that under the ON/ON condition with the exception of the pausing observed at the beginning of the second component during the ON/OFF condition. Reinstating the OFF/ON condition immediately elevated first-component response rates (record E—first session) and record F—final session) and, as during the previous exposure to the OFF/ON condition, a positively accelerated pattern of responding was maintained in both components. Although the elevation in first-component response rate was greatest during the initial session of this condition, first-component response rates remained elevated during the OFF/ON condition and were higher than those in all other conditions. Removal of houselight illumination during both components in the OFF/OFF condition (record G) resulted in rates and patterns of responding in both components comparable to those during both exposures to the ON/ON condition (records A and H).

For both Pigeons P-4214 and P-3519, performance when the houselight was illuminated during both components of the chained FI 2-min FI 2-min was characterized by low response rates during the first component. Transition to the second component produced a high, constant response rate for Pigeon P-4214 and pausing followed by a high, constant response rate for Pigeon P-3519. Pausing increased and responding became more positively accelerated in the second component for both pigeons in the first session with the houselight illuminated during only the second component (OFF/ON).

First-component response rates increased for both pigeons within the first session of the OFF/ON condition. However, unlike the results with Pigeon P-1150, this increase in first-component response rates diminished within each session. Typically, each session began with high first-component response rates continuing for approximately one-third of the session. By the end of the session, responding maintained during the first component had decreased to those levels found in the ON/ON condition. In an effort to minimize the tendency for first-component response rates to diminish within the session, the durations of the component schedules were reduced from 2 min to 1 min for both Pigeons P-4214 and P-3519. As previously noted, this schedule remained in effect for the rest of the experiment for both pigeons.

When the houselight was illuminated subsequently during both components (ON/ON), pausing increased and response rates decreased substantially during the first component for Pigeon P-4214. First-component response rates were comparably low under the ON/OFF and OFF/OFF conditions. Reinstatement of the OFF/ON condition again produced an immediate high rate of responding during the first component, which was either maintained throughout the session or diminished somewhat as the session progressed. As with Pigeon P-1150, pausing at the onset of the second component was greatest under the OFF/ON conditions and shortest under the ON/ON conditions.

In contrast to the results obtained with Pigeons P-1150 and P-4214, the first exposure to the ON/OFF condition with Pigeon P-3519 produced first-component response rates comparable to those generated under the preceding OFF/ON condition. The OFF/ON and ON/OFF conditions were then alternated. First-component response rates were elevated immediately during the first session of each OFF/ON condition. First-component response rates decreased during the second exposure to the ON/OFF condition. In five of the six possible comparisons between the OFF/ON and ON/OFF conditions, first component response rates were higher under the OFF/ON condition for Pigeon P-3519. Pausing during the second component was
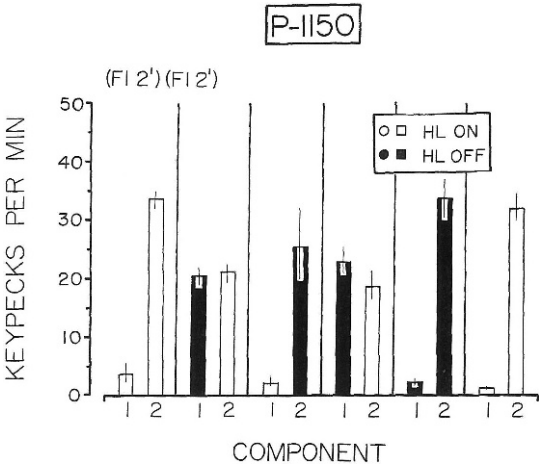
Fig. 2. Median session values for keypecks per min from the last 20 sessions of each condition of Experiment 1 for Pigeon P-1150. Vertical lines at the top of each bar represent interquartile ranges for those sessions. Filled histograms represent conditions in which the houselight was off, while unfilled histograms are from those in which the houselight was illuminated.

Fig. 4. Median session values for keypecks per min from the last 20 sessions of each condition of Experiment 1 for Pigeon P-3519. See Figure 2 for details.

greatest during the OFF/ON conditions and shortest during the ON/ON conditions, similar to Pigeons P-1150 and P-4214.

Quantitative summaries of the results are shown in Figures 2, 3, and 4 for Pigeons P-1150, P-4214, and P-3519, respectively. These data are the median response rates over the last 20 sessions in each condition. For Pigeon P-1150, first-component response rates were consistently low under the ON/ON, ON/OFF,
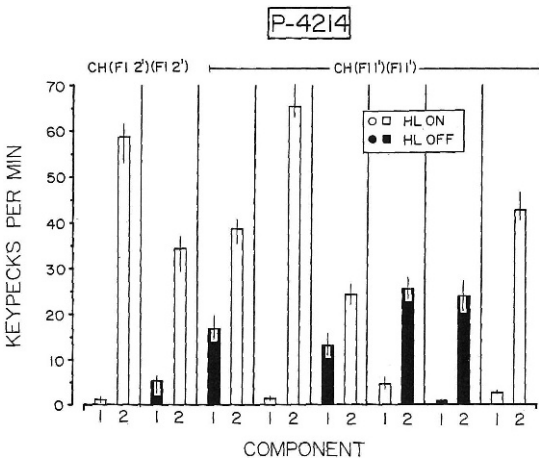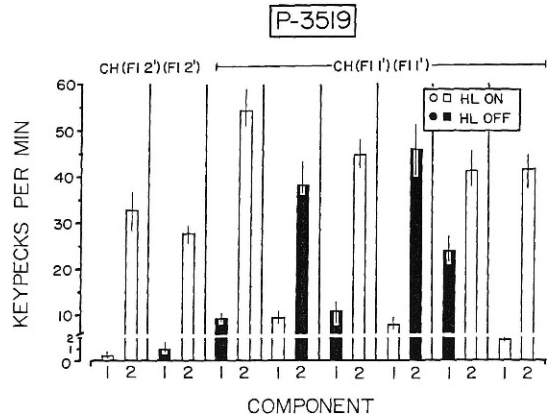
and OFF/OFF conditions. Under the OFF/ON conditions, first-component response rates were as much as six times that of any other arrangement. For Pigeon P-4214, first-component response rates under the OFF/ON conditions were approximately three to six times that of any other condition. For Pigeon P-3519, the final exposure to the OFF/ON condition generated response rates during the first component more than twice that under any other condition.

DISCUSSION

For each pigeon in Experiment 1 the rate of responding during the first component of a two-component chained schedule increased substantially when the houselight was illuminated following the first component(OFF/ON). No other configuration of houselight illumination across the two components resulted in consistent enhancement of response rates during the first component. Pausing at the beginning of the second component was greatest during the OFF/ON condition.

Two possibilities can be offered to account for the increased rate of responding during the first component under the OFF/ON condition. First, changes in houselight illumination may have augmented the existing stimulus control exerted by the component stimuli (i.e., the keylight colors). Second, the onset of houselight illumination may have functioned to reinforce responding during the first component. Gollub (1958) reported that response rates during the first component of a

Fig. 3. Median session values for keypecks per min from the last 20 sessions of each condition of Experiment 1 for Pigeon P-4214. See Figure 2 for details.

two-component chained schedule exceeded those during the first component of a comparable tandem schedule (i.e., one in which primary reinforcement is presented following the completion of a sequence of schedule components that are not associated with distinct discriminative stimuli). In Gollub's procedures, the stimulus associated with the first component of the chained schedule was the same as that present throughout the tandem condition and thus may have occasioned a higher rate of responding in the first component than would have occurred had a different stimulus been present.

In the current experiment, the keylight colors associated with the two component schedules may have exerted insufficient stimulus control to generate responding appropriate to the two component schedules independently. That is, performance may have been more characteristic of that maintained under a comparable tandem schedule. Presentation of houselight illumination during only the second component may have enhanced the stimulus difference (and the discriminability) between the two components, allowing each stimulus to maintain schedule-appropriate performances (i.e., higher response rates during the first component and increased pausing at the beginning of the second component). However, two aspects of the present results argue against this interpretation. First, the two component schedules produced diverse rates and patterns of responding prior to any manipulation of houselight illumination. Thus, the component stimuli in the ON/ON condition were discriminable. Second, although the two components should be equally discriminable during the OFF/ON and ON/OFF conditions, response rates during the first component were much greater under the OFF/ON condition. Thus, the increased rate of responding during the first component under the OFF/ON condition would appear to be the result of the contingent presentation of houselight illumination per se.

Previous studies have demonstrated that changes in illumination can function as primary reinforcers (cf., Kish, 1966). However, these demonstrations and the present experiment differ along several dimensions, including species and procedures employed, as well as the magnitude of the rate enhancement observed. The elevation in first-component response rates under the OFF/ON conditions was many times greater than rate of responding when a change in illumination was the only scheduled consequence for responding (e.g., Stewart, 1960). In fact, the increase in first-component response rates in the OFF/ON conditions is similar to the increase in first-component response rates when a food-paired brief stimulus is interpolated between components during a two-component chained schedule of food presentation (Malagodi et al., 1973). This similarity suggests that the potential reinforcing properties of houselight illumination might be derived through association with some aspect of food presentation. Experiments 2 and 3 assessed two possible sources of the reinforcing properties of houselight illumination.

EXPERIMENT 2

In brief, Experiment 1 showed that first-component response rates were enhanced during a two-component chained schedule when the onset of houselight illumination occurred with the second component schedule. Houselight illumination at the completion of the first component may have functioned to reinforce first-component responding as a result of becoming a conditioned reinforcer through the temporal proximity of illumination to food presentation at the end of the second component. Stimuli associated with the terminal component of a chained schedule are present immediately prior to the presentation of primary reinforcement and, consistent with many conceptualizations regarding the formation of conditioned reinforcers, this temporal contiguity is sufficient to imbue the terminal component stimuli with reinforcing properties (e.g., Gollub, 1977; Kelleher, 1966b; Kelleher & Gollub, 1962; Marr, 1969). As noted earlier, three classes of manipulations have been employed to assess the reinforcing properties of stimuli associated with the terminal component of chained schedules: changes in the order of presentation of component stimuli (e.g., Byrd, 1971; Ferster & Skinner, 1957; Jwaideh, 1973; Kelleher & Fry, 1962); alterations in the rate or probability of reinforcement in the terminal component (e.g., Autor, 1969; Ferster & Skinner, 1957; Kaufman & Baron, 1969); and

brief presentation of the terminal component stimulus during other component schedules (Marr, 1969).

In brief, this research has shown that (a) schedule-appropriate patterns of responding are maintained by an established terminal component stimulus regardless of its altered order within a chained schedule (e.g., Byrd, 1971; Ferster & Skinner, 1957; Jwaideh, 1973; Kelleher & Fry, 1962), (b) the reinforcing strength of the terminal component stimulus is related directly to the rate or probability of reinforcement in its presence (e.g., Autor, 1969; Ferster & Skinner, 1957; Findley, 1954, 1962; Hanson & Witoslawski, 1959; Herrnstein, 1961, 1964; Kaufman & Baron, 1969), and (c) contingent brief presentations of terminal component stimuli within other components of a chained schedule can increase the ongoing rate of responding in those component schedules (Marr, 1969).

Overall, these findings would support the suggestion that the temporal arrangement of houselight illumination in the OFF/ON conditions of Experiment 1 could establish houselight illumination as a conditioned reinforcer for responding during the first component. Experiment 2 employed a 3-component chained FI FI FI schedule to compare the effects of contingent houselight illumination under conditions in which illumination was and was not associated with the terminal component. Under a chained FI FI FI schedule each component-schedule stimulus may occasion a different rate of responding. The first component stimulus often occasions prolonged periods of no responding, and the first component schedule is often completed after the occurrence of only a single response. The second component generally produces a moderate rate of responding. The onset of the third component generally occasions an abrupt transition to a high rate of responding that continues until the presentation of the primary reinforcer.

METHOD

Subjects

Three adult male White Carneau pigeons (Pigeons P-1150, P-2225, and P-3775) were maintained at 80% of their free-feeding weights. Each had previous exposure to simple schedules of reinforcement. Pigeon P-1150 had served in Experiment 1. Each pigeon was individually housed with water and health grit continuously available.

Apparatus

The apparatus was the same as that employed in Experiment 1.

Procedure

Throughout Experiment 2 responding was maintained according to a three-component chained schedule of food presentation: chained FI 2-min FI 2-min FI 2-min for Pigeon P-1150 and chained FI 1-min FI 1-min FI 1-min for Pigeons P-2225 and P-3775. During the first component the response key was illuminated blue and during the second and third components the response key was illuminated yellow and red, respectively. The presence of houselight illumination in each of the components was manipulated across experimental conditions. The order of experimental conditions and the number of sessions under each are shown in Table 2.

Sessions terminated following the completion of 10 grain presentations for Pigeon P-1150 and 20 grain presentations for Pigeons P-2225 and P-3775. Total duration and number of responses were recorded by component within each session. From these measures, average component response rates were derived for each session. All other procedural aspects were identical to those described in Experiment 1.

RESULTS

Performances typical of three-component chained schedules (Kelleher & Gollub, 1962) developed for each pigeon in Experiment 2. Representative cumulative records from each experimental condition for Pigeon P-1150 are shown in Figure 5. Each record represents the final session of a condition, except the first session of the OFF/ON/ON and OFF/OFF/ON conditions are also displayed.

With the houselight illuminated throughout each component (ON/ON/ON), first-component response rates characteristically were low, second-component response rates were moderate, and response rates during the third component were constant and high for Pigeon P-1150 (record A). They were also high and constant in the third component

Table 2

Summary of Experiment 2 conditions.

Pigeon	Schedule	Houselight Condition	Number of Sessions
P-1150	CH (FI 2-m)(FI 2-m)(FI 2-m)	ON/ON/ON	38
	CH (FI 2-m)(FI 2-m)(FI 2-m)	OFF/ON/ON	30
	CH (FI 2-m)(FI 2-m)(FI 2-m)	OFF/ON/OFF	48
	CH (FI 2-m)(FI 2-m)(FI 2-m)	OFF/OFF/ON	46
	CH (FI 2-m)(FI 2-m)(FI 2-m)	ON/ON/ON	55
P-2225	CH (FI 1-m)(FI 1-m)(FI 1-m)	ON/ON/ON	50
	CH (FI 1-m)(FI 1-m)(FI 1-m)	OFF/ON/ON	158
	CH (FI 1-m)(FI 1-m)(FI 1-m)	OFF/OFF/ON	63
	CH (FI 1-m)(FI 1-m)(FI 1-m)	OFF/ON/OFF	50
	CH (FI 1-m)(FI 1-m)(FI 1-m)	ON/ON/ON	117
P-3775	CH (FI 1-m)(FI 1-m)(FI 1-m)	ON/ON/ON	42
	CH (FI 1-m)(FI 1-m)(FI 1-m)	OFF/ON/ON	38
	CH (FI 1-m)(FI 1-m)(FI 1-m)	OFF/OFF/ON	96
	CH (FI 1-m)(FI 1-m)(FI 1-m)	OFF/ON/OFF	32
	CH (FI 1-m)(FI 1-m)(FI 1-m)	ON/ON/ON	78

for Pigeons P-2225 and P-3775. For Pigeon P-3775, responding in the third component was characterized by a pause followed by positively accelerated responding until food presentation. Because of the pausing, response rates in the third component were lower than those in the second component for both Pigeons P-2225 and P-3775.

When the houselight was illuminated during only the second and third components (OFF/ON/ON), response rates during the first component increased dramatically. For each pigeon this rate enhancement was evident in the first session of the OFF/ON/ON condition (record B) and was sustained throughout the subsequent exposure to this condition (record C). Although average response rates were enhanced during the first component in the OFF/ON/ON condition, first-component response rates were greatest at the beginning of a session and often decreased as the session progressed. By contrast, second-component response rates were substantially reduced, especially for Pigeon P-1150, and the performances of Pigeon P-2225 and Pigeon P-3775 were characterized by pausing followed by positively accelerated responding until the onset of the third component. A similar pattern of responding was observed in the third component for all 3 pigeons.

First-component response rates remained elevated when the houselight was illuminated in only the second component (OFF/ON/ OFF). First-component response rates were higher for Pigeon P-1150 (record D) and Pigeon P-2225 than for Pigeon P-3775.

First-component response rates tended to decrease as the session progressed for each pigeon. Second-component response rates were comparable to those under the OFF/ ON/ON conditions for each pigeon.

Illumination of the houselight during only the third component (OFF/OFF/ON) generated high and steady second-component response rates for Pigeon P-1150 (records E and F) but without a notable decline as the session progressed. The second-component response rates for Pigeons P-2225 and P-3775 were comparable to those in the ON/ON/ ON condition. The reinstatement of the ON/ ON/ON condition produced response patterns generally similar to those obtained in the initial condition (record G). Figures 6, 7, and 8 show median session response rates for each component over the last 20 sessions of each condition of Experiment 2 for Pigeons P-1150, P-2225, and P-3775, respectively. The contingent onset of houselight illumination during the second component enhanced first-component response rates from 4 to 20 times over those under the ON/ON/ON conditions, whether or not houselight illumination occurred in the third component. Illumination of the houselight in only the third component (OFF/OFF/ON) increased second-component response rates approximately 7 times over that in the ON/ON/ON condition for Pigeon P-1150. For both Pigeons P-2225 and p-3775 response rates in the second component were comparable under the OFF/OFF/ON and ON/ON/ON conditions.
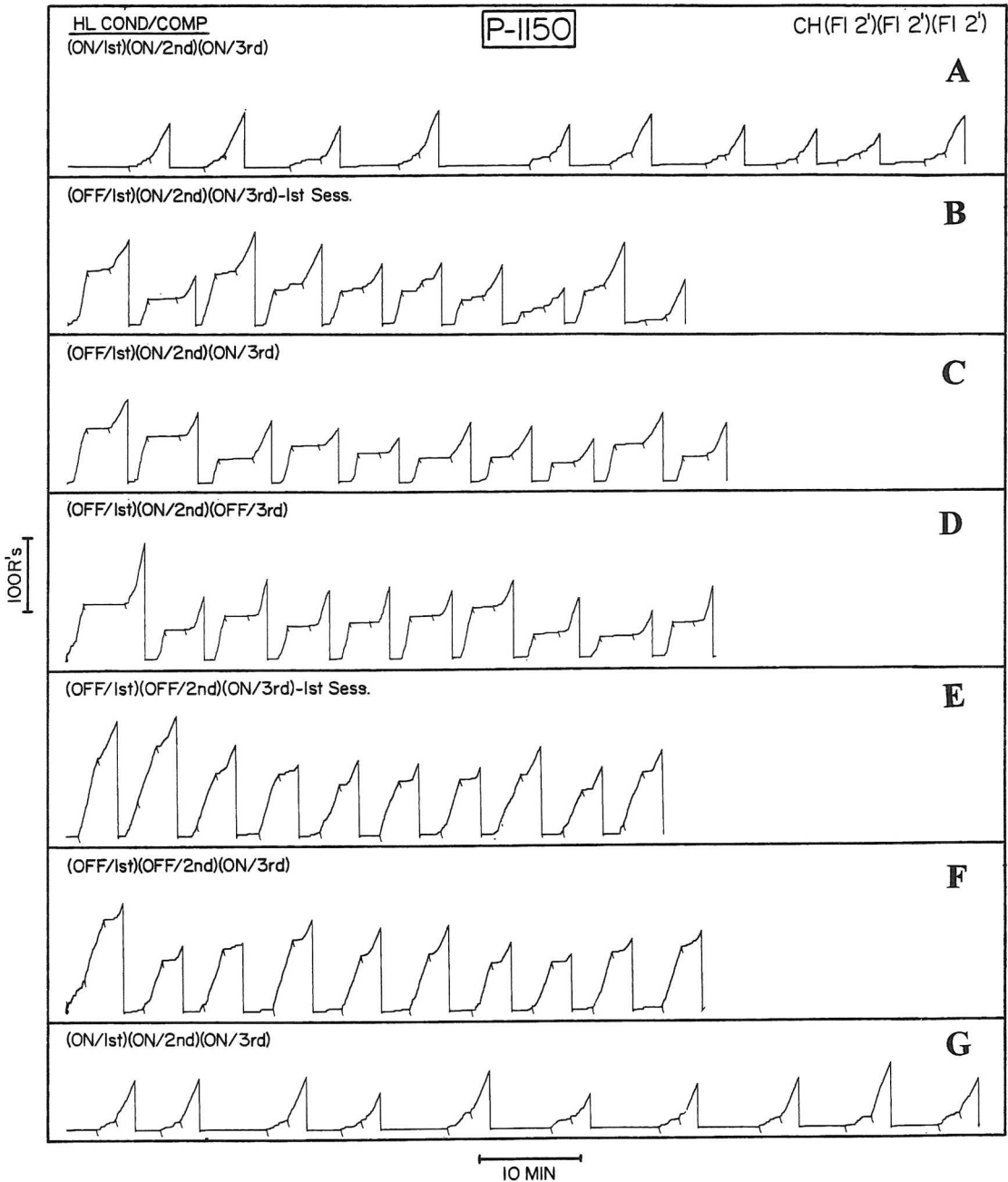
Fig. 5. Sample cumulative records from each condition of Experiment 2 for Pigeon P-1150. Diagonal marks represent completion of the first and second components, and reset of the response pen represents completion of the third component.

DISCUSSION

As in Experiment 1, response rates in the first component of a chained schedule were considerably enhanced when the houselight was illuminated at the onset of the second component. These results expand the generality of the previous experiment to an extended chained schedule. Additionally, the rate-enhancing effects of contingent houselight illumination were sustained regardless of
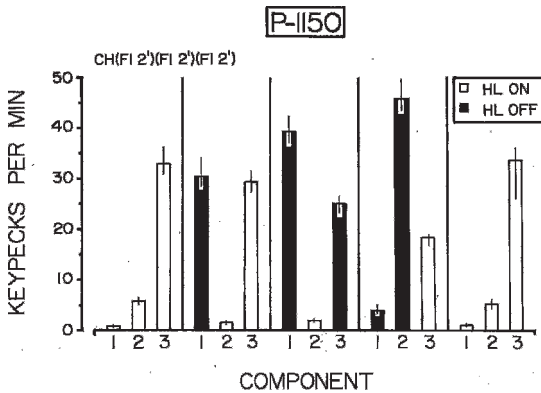
Fig. 6. Median session values for keypecks per min from the last 20 sessions of each condition of Experiment 2 for Pigeon P-1150. Vertical lines at the top of each bar represent interquartile ranges for those sessions. Filled histograms represent conditions in which the houselight was off, while unfilled histograms are from those in which the houselight was illuminated.

Fig. 8. Median session values for keypecks per min from the last 20 sessions of each condition of Experiment 2 for Pigeon P-3775. See Figure 6 for details.

whether the houselight was illuminated during the third component. Thus, these results do not support the interpretation that the rate-enhancing effects of houselight illumination onset are the result of presenting houselight illumination in the terminal component. It may be argued that the enhancement of first-component response rates in the OFF/ON/OFF condition represents the residual reinforcing properties acquired by the illuminated
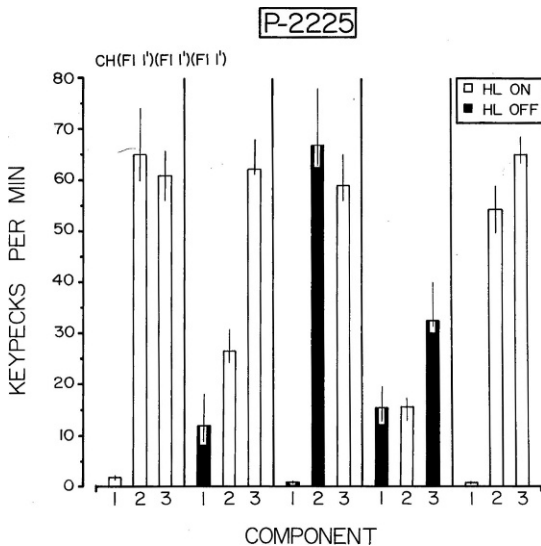

Fig. 7. Median session values for keypecks per min from the last 20 sessions of each condition of Experiment 2 for Pigeon P-2225. See Figure 6 for details.
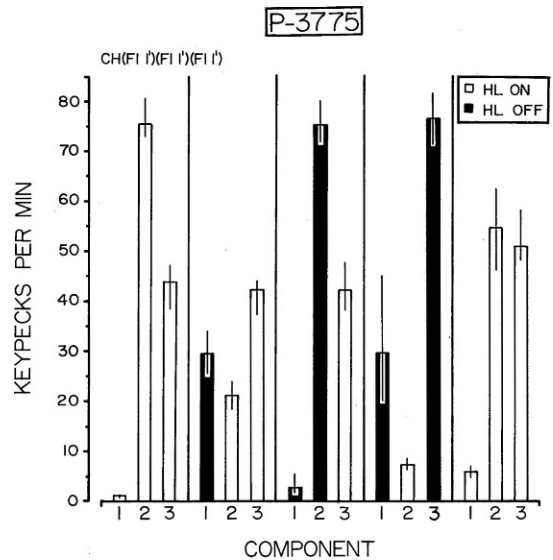
houselight through previous association with the terminal component. However, the large number of sessions conducted in the OFF/ON/OFF condition (32, 48, and 50 sessions for Pigeons P-3775, P-1150, and P-2225, respectively) without decreases in first component response rates argues against this interpretation.

That second-component response rates for Pigeons P-2225 and P-3775 were not enhanced in the OFF/OFF/ON condition above those under the preceding ON/ON/ON condition may be due to the already high response rates maintained by that component schedule. For both pigeons, second-component response rates exceeded third-component response rates in the initial exposure to the ON/ON/ON condition. However, for Pigeon P-1150, second-component response rates in the ON/ON/ON condition were considerably lower than those in the third component but were significantly enhanced under the OFF/OFF/ON condition. Reinforcing stimuli made contingent on high-rate behaviors do not always enhance response rates and may lower them (e.g., Skinner & Morse, 1958). Additionally, the prevailing rate of responding is one of several important determinants of not only reinforcement and punishment effects (Morse & Kelleher, 1977) but also the effects of a

variety of independent variables, such as psychoactive pharmaceutical agents (Kelleher & Morse, 1968).

While the pairing of houselight illumination with the terminal component was not necessary for the houselight illumination to function as a reinforcer, it is possible that another aspect of the chained schedule procedures is the source of the reinforcing property. Experiment 3 examined whether stimulus generalization from the illumination of the feeder during food presentation is necessary for houselight illumination to function as a reinforcer under the current procedures.

EXPERIMENT 3

The stimulus most strongly correlated with food presentation in many operant experimental arrangements is the illumination of the food hopper. With pigeons as subjects, food presentation generally is accompanied by the offset of the keylight and houselight, and by direct illumination of the feeder tray. Thus, feeder-light illumination immediately precedes and coincides with eating from the tray. Within most conceptualizations of conditioned reinforcement, this temporal arrangement of feeder-light illumination and food presentation is considered sufficient to establish the feeder light as a conditioned reinforcer (e.g., Gollub, 1977; Kelleher, 1966a; Kelleher & Gollub, 1962; Marr, 1969).

Numerous studies have demonstrated the reinforcing properties of contingent feeder-light illumination (e.g., de Lorge, 1971; Findley and Brady, 1965; Malagodi et al., 1973). Findley and Brady reported both a dramatic decrease in preratio pausing and increase in overall response rate by a chimpanzee responding according to a fixed-ratio 4000 schedule of food delivery when each 400th response resulted in the brief illumination of the feeder. Similarly, the brief illumination of the feeder light interpolated between component stimuli in a two-component chained schedule generated first-component response rates by pigeons that were comparable to those obtained when food was presented at the completion of each component (Malagodi et al., 1973). Throughout Experiments 1 and 2 the houselight and feeder light were white and comparably intense. Stimulus generalization between the two sources of

illumination may have been responsible for the apparent reinforcing characteristics of houselight illumination. Experiment 3 assessed this possibility by manipulating the presence of houselight illumination during the first component of a three-component chained schedule once the colors and intensities of the houselight and feeder-light were no longer the same.

METHOD

Subjects

The subjects were the same as in Experiment 2.

Apparatus

The apparatus employed was the same as in Experiment 2 except that an additional 1.4W light was mounted above the feeder and covered with a green translucent cap.

Procedure

The chained schedules and keylight stimuli were the same as those in Experiment 2. The present experiment consisted of three phases. In the first, the houselight was illuminated during each component (ON/ON/ON) and the feeder light was illuminated green during grain presentations but was illuminated white between grain presentations. In the second, the houselight was illuminated during only the second and third components (OFF/ON/ON), but the feeder light was the same as in the first condition. In the final condition, the OFF/ON/ON condition was continued but with no feeder-light illumination between grain presentations. The order of experimental conditions and the number of sessions under each are shown in Table 3. All other procedural aspects were identical to those described in Experiment 2.

RESULTS

Despite the change in feeder-light conditions, rates and patterns of responding typical of three-component chained schedules developed and were maintained in the ON/ON/ON condition. Representative cumulative records from each condition of Experiment 3 for Pigeon P-1150 are displayed in Figure 9. Each record represents the final session of a condition, with the exception that the first session of the OFF/ON/ON condition is also

Table 3

Summary of Experiment 3 conditions.

| Pigeon	Schedule Feeder light Condition	Houselight Condition	Number of Sessions
P-1150	FI 2-min FI 2-min FI 2-min Green feeder light during reinforcement; white feeder light otherwise	ON/ON/ON	59
	FI 2-min FI 2-min FI 2-min Green feeder light during reinforcement; white feeder light otherwise	OFF/ON/ON	53
	FI 2-min FI 2-min FI 2-min Green feeder light during reinforcement; no feeder light otherwise	OFF/ON/ON	26
P-2225	FI 1-min FI 1-min 1-min Green feeder light during reinforcement; white feeder light otherwise	ON/ON/ON	51
	FI 1-min FI 1-min FI 1-min Green feeder light during reinforcement; white feeder light otherwise	OFF/ON/ON	53
	FI 1-min FI 1-min FI 1-min Green feeder light during reinforcement; no feeder light otherwise	OFF/ON/ON	32
P-3775	FI 1-min FI 1-min FI 1-min Green feeder light during reinforcement; white feeder light otherwise	ON/ON/ON	66
	FI 1-min FI 1-min FI 1-min Green feeder light during reinforcement; white feeder light otherwise	OFF/ON/ON	46
	FI 1-min FI 1-min FI 1-min Green feeder light during reinforcement; no feeder light otherwise	OFF/ON/ON	27
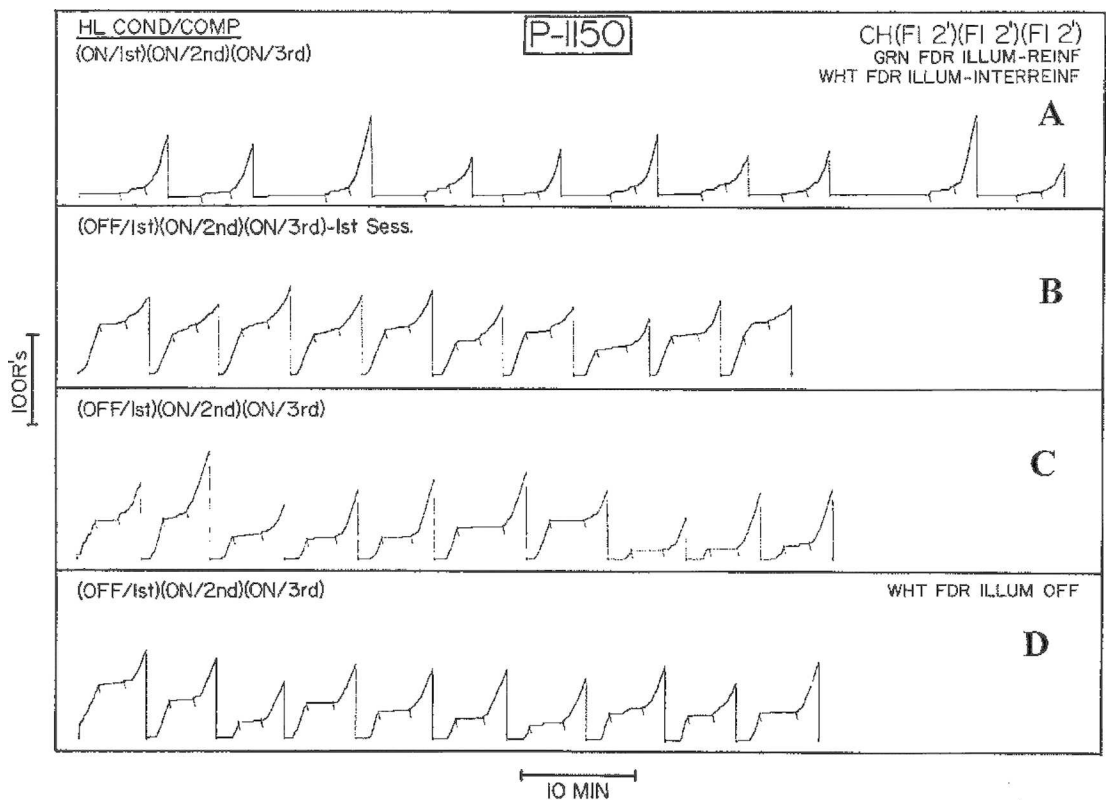
Fig. 9. Sample cumulative records from each condition of Experiment 3 for Pigeon P-1150. Diagonal marks represent completion of the first and second components, and reset of the response pen represents completion of the third component.

displayed. For each pigeon, responding was generally similar to that observed in the ON/ON/ON conditions of Experiment 2, with the exception of the lower overall rate of responding exhibited by Pigeon P-2225.

When the houselight was illuminated during only the second and third components (OFF/ON/ON), first-component response rates were elevated within the initial session (record B). First-component response rates remained elevated throughout the condition; however, they tended to decrease as the session progressed (record C). Response rates in the second component were reduced from that observed in the preceding ON/ON/ON condition for each pigeon. Removal of the white feeder-light illumination between grain presentations had no consistent effect on responding across subjects (record D). Quantitative summaries of median response rates per component for each condition of Experiment 3 are shown in Figures 10, 11, and 12 for Pigeons 1150, 2225, and 3775, respectively.

No systematic change in responding accompanied the removal of the white feeder-light illumination between grain presentations. First-component response rates in the OFF/ON/ON conditions ranged from 5 to 70 times greater than that under the ON/ON/ON condition. Second-component response rates during the OFF/ON/ON conditions decreased for each pigeon from that during the ON/ON/ON condition. Third-component response rates decreased during the OFF/ON/ON conditions for Pigeons P-1150 and P-2225 from those during the ON/ON/ON condition, but increased for Pigeon P-3775.

DISCUSSION

Experiment 3 examined the possibility that the apparent reinforcing properties of houselight illumination demonstrated in Experiments 1 and 2 were the results of stimulus generalization from the feeder-light illumination present during grain presentation. This was accomplished by changing the feeder-light illumination during grain presentation from white to green, while concurrently presenting the white feeder light throughout the interreinforcement period. These two changes were made to (a) reduce the similarity between houselight and feeder-light illumination; and (b) pair the white feeder light with periods of nonreinforcement in order to reduce or
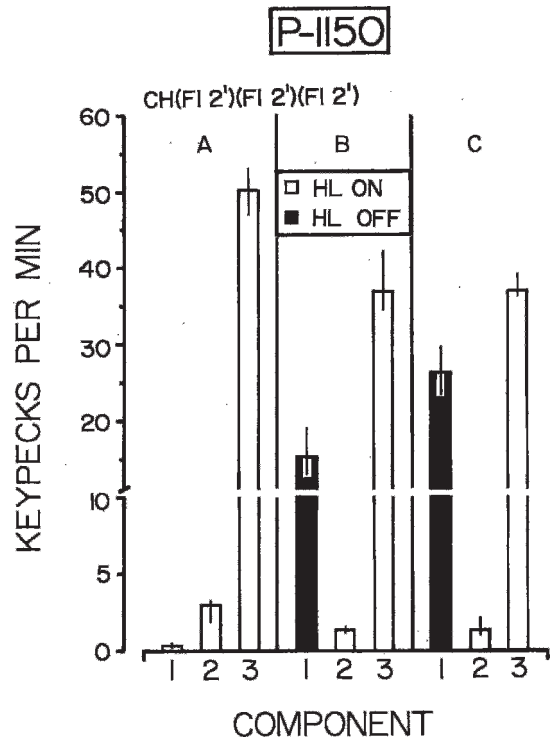

Fig. 10. Median session values for keypecks per min from the last 20 sessions of each condition of Experiment 3 for Pigeon P-1150. Vertical lines at the top of each bar represent interquartile ranges for those sessions. Filled histograms represent conditions in which the houselight was off, while unfilled histograms are from those in which the houselight was illuminated. In conditions A and B, the feeder was illuminated green during grain delivery and a white feeder light was on throughout the interfood period. In condition C the white feeder light was off.

eliminate any existing conditioned reinforcing effects of white illumination.

Although contingent feeder-light illumination repeatedly has been shown to function as a potent conditioned reinforcer (e.g., Findley & Brady, 1965; Malagodi et al., 1973), generalization from the feeder light to houselight illumination does not appear to be responsible for the rate-enhancing properties of contingent houselight illumination in the present set of experiments. First-component response rates in the OFF/ON/ON conditions were 5 to 70 times greater than those in the ON/ON/ON condition despite reductions in the similarities of feeder-light and houselight illumination. However, it should be noted that the response-rate enhancement during the first component of the OFF/ON/ON condition of the present experiment was less than
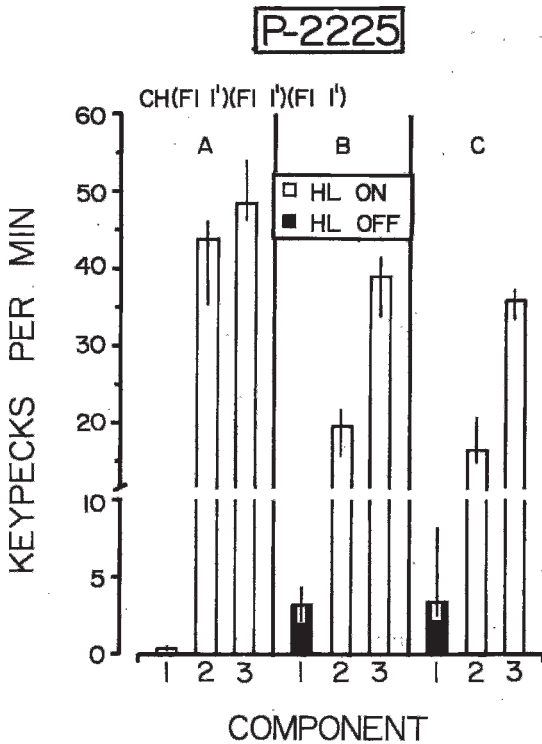
Fig. 11. Median session values for keypecks per min from the last 20 sessions of each condition of Experiment 3 for Pigeon P-2225. See Figure 10 for details.

that during Experiment 2 for Pigeons 1150 and 2225. Thus, although the similarity of feeder-light and houselight illumination may have contributed to the enhancement in first-component response rates under the OFF/ON/ON condition of Experiment 2, the apparent reinforcing effects of contingent houselight illumination do not appear to result solely from that generalization.

GENERAL DISCUSSION

In each of the present experiments, the rate of responding within one component of a two- or three-component chained schedule increased substantially when the chamber house-light was illuminated at the completion of that component. Experiment 1 demonstrated that this rate enhancement was neither the result of component stimulus control augmented by differential houselight illumination within component schedules, nor the disinhibition of responding following the removal of house-light illumination. Instead, the results of
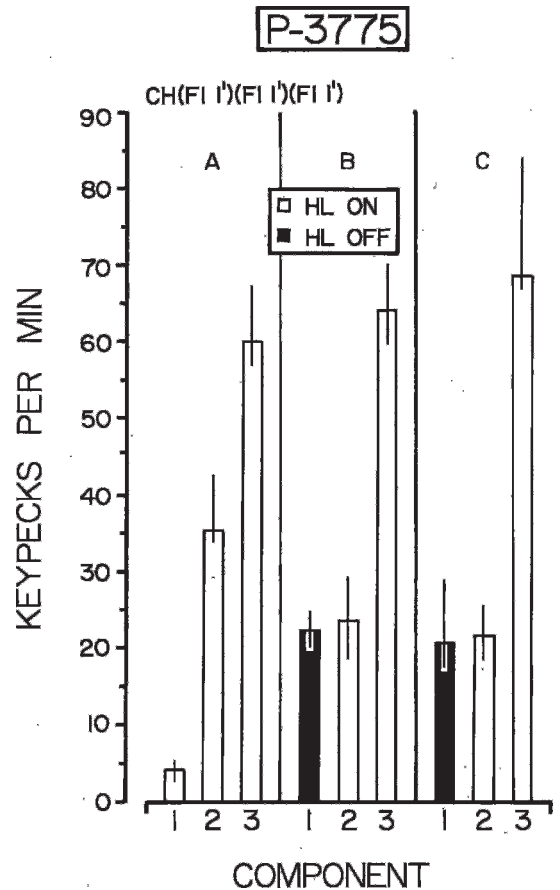

Fig. 12. Median session values for keypecks per min from the last 20 sessions of each condition of Experiment 3 for Pigeon P-3775. See Figure 10 for details.

Experiment 1 were consistent with the inter-pretation that the onset of houselight illumi-nation is a positive reinforcer. Experiments 2 and 3 assessed two potential sources from which houselight illumination may have ac-quired conditioned reinforcing properties. The results of these two experiments suggest that the reinforcing effect of houselight illumination resulted from neither the tempo-ral contiguity between houselight illumination and the terminal component of the chained schedule nor from stimulus generalization from the feeder light to the houselight.

Other theoretical conceptualizations of the formation of conditioned reinforcers appear less applicable to the present experimental procedures. According to the delay-reduction hypothesis (e.g., Fantino, 1969, 1977), a houselight illuminated in only the latter

components of a chained schedule might function as a conditioned reinforcer by virtue of signaling a reduction in the time to the presentation of the primary reinforcer. Uncertainty-reduction theories (e.g., Bloomfield, 1972) might suggest that an illuminated houselight, differentially associated with the latter components of a chained schedule, would acquire reinforcing properties by providing ''information'' or a reduction in uncertainty regarding the presentation of primary reinforcement. However, across all conditions in the present series of experiments, the illuminated houselight was accompanied by and redundant with the component keylight stimuli and, thus, should have no greater reinforcing effect than the component stimuli themselves. In fact, any preexisting conditioned reinforcing and discriminative properties of the component stimuli may have functioned to block the acquisition of such properties by the houselight (Rescorla and Wagner, 1972).

However, signaling the presentation of reinforcement may affect responding in other ways. The presentation of a brief stimulus (e.g., tone or light) signaling the delivery of reinforcement can either increase or suppress responding depending on a variety of factors. For example, the onset of diffuse light (such as that from the houselight in the present set of experiments) signaling the presentation of reinforcement enhances overall response rate, while the presentation of a more localized light (as with a transilluminated response key)results in decreased responding (Reed, Schachtman, & Hall, 1988). Additionally, stimuli signaling the delivery of reinforcement imposed upon schedules generating higher, rather than lower, rates of responding can enhance ongoing responding (Reed, 2003). The response-learning view (Reed, 1989) suggests that the signal may highlight or reinforce the pattern of behavior—aggregations of either shorter or longer interresponse times (IRTs), for example—that occur prior to reinforcement. In effect, this pattern of IRTs would come to constitute a new functional unit of behavior whose reinforcement would alter overall rates of responding. In the present set of experiments, the contingent presentation of the houselight illumination associated with the relatively higher rate of responding at the completion of a component schedule may have resulted in increased rates of responding during the component schedule preceding houselight onset. This view might suggest that response rates in component schedules immediately preceding houselight illumination would not be enhanced if a variable-interval schedule rather than a fixed-interval schedule was employed as the component schedule.

It is unclear whether, under the current procedures, contingent houselight illumination functioned as a signal helping to differentiate functional units of behaviors, as a conditioned reinforcer established through some unidentified operation, or as an unconditioned reinforcer. As previously cited, numerous studies have shown that the onset of illumination can function to reinforce responding (e.g., Girdner, 1953; Kish, 1955; Kling, Hurwitz, & Dalhagen, 1956; Marx, Henderson, & Roberts, 1955; Reed, Collinson, & Nokes, 1995; Segal, 1959; Stewart, 1960). Other studies have reported that the termination of illumination can function as a negative reinforcer (e.g., Barry & Symmes, 1963; Keller, 1941; Roberts, Marx, & Collier, 1958). These data led to the inclusion of changes in illumination in a suggested class of stimuli termed sensory reinforcers (Kish, 1966), whose reinforcing effects are derived neither through an identified ''need'' or deprivation state nor association with an established reinforcer.

Although the results of the present series of experiments can be related to these findings, the magnitude of the present effect is several times greater than that reported in previous studies. For individual subjects in the present study, the increase in first-component response rates when the onset of houselight illumination occurred in the second component was as great as 25 responses per min (e.g., Pigeon P-1150 in Experiment 3). In contrast, rate enhancement with contingent illumination change was on the order of 1 to 3 responses per min in the other experimental arrangements. Such differences in the level of the effect might be attributed to procedural differences between the present and previous experiments. These differences include: (a) the use of pigeons as subjects rather than mice (e.g., Kish, 1955), rats (e.g., Hurwitz & Appel, 1959), or monkeys (e.g., Moon & Lodahl, 1956); and (b) the superimposition of

contingent illumination change on an existing food reinforcement schedule rather than presented as the sole consequence of responding under either continuous or intermittent reinforcement schedules (Stewart, 1960). It has been demonstrated repeatedly that the reinforcing effect of various activities that may be concurrently available with reinforcement schedules (i.e., so-called schedule-induced behaviors such as wheel running, water drinking, aggressing against a restrained conspecific, etc.) is modulated by schedule characteristics, such as reinforcement rate and predictability (cf., Falk, 1971). Therefore, it is possible that the reinforcing effect of houselight illumination in the present experiments was augmented through induction from the ongoing schedule of food presentation.

Premack (1965) has suggested that access to ''high-probability behaviors'' will reinforce ''low-probability behaviors.'' For example, for a food-deprived subject, eating is a high-probability behavior. Thus, access to eating would function to reinforce low-probability behavior (e.g., keypecking or lever pressing) in a contingent relationship. Similarly, the Response Deprivation Theory (Timberlake & Allison, 1974) suggests that activities or behaviors that are constrained to a point below their operant or baseline level will function to reinforce behaviors in a contingent relationship. Eating for a food-deprived subject would be an activity constrained to a lower rate or amount than under baseline conditions; thus, access to eating would function to reinforce a relatively less restricted behavior, such as keypecking or lever pressing. In the current set of experiments, removal of houselight illumination during a component schedule may have deprived the pigeons of access to behaviors that could only occur in an illuminated environment (e.g., pecking at visible objects in the chamber). The illumination of the houselight in the subsequent component may have been reinforcing because these deprived behaviors could again occur.

Regardless of the provenance of the reinforcing properties of houselight illumination, the present results bear on other experiments in which changes in illumination have been employed as arbitrary or neutral experimental stimuli. For example, alterations in houselight illumination have been employed to signal self-imposed timeout periods during studies of schedule-induced escape (e.g., Appel, 1963; Azrin, 1961; Brown & Flory, 1972; Dardano, 1973; Thomas & Sherman, 1965; Thompson, 1964). Under such procedures, it may be difficult to distinguish the possible negative reinforcing effects of timeout onset and the possible positive reinforcing effects of changes in houselight illumination. Also, as previously mentioned, houselight illumination has been employed as a brief stimulus in comparisons of the performances maintained under paired and nonpaired brief-stimulus schedules (cf. Stubbs, 1971). These studies have attempted to assess possible reinforcing properties of brief stimuli intermittently paired with a primary reinforcer. However, the contingent illumination of the houselight might have acted as a reinforcer whether or not it was paired with a primary reinforcer and confounded any effects of the pairing operation.

Given the present results, and those of previous studies demonstrating illumination-reinforced responding, care should be taken when employing houselight illumination as an experimental stimulus.

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